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FACULDADE DE MEDICINA VETERINÁRIA

A Comparison between Conventional and Nutridense corn on the Digestibility and Performances of Broilers

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Resumo

Foi realizado um ensaio experimental de digestibilidade e dois de performance, com frangos de carne, para comparar o valor alimentar do milho convencional (CC) com milho Nutridense (ND).

No ensaio de digestibilidade, 288 frangos foram seleccionados e divididos por dois tratamentos com 92.25% de CC (tratamento 1) e de ND (tratamento 2). Foi medida a digestibilidade da energia e dos aminoácidos nos animais. Galos foram também usados para o mesmo objectivo. Os resultados, indicaram que a energia metabolizável do ND é superior à do CC mas na digestibilidade dos aminoácidos, os dois milhos não mostraram diferenças significativas.

Em performance, no primeiro ensaio, 384 frangos foram seleccionados e divididos por 6 tratamentos. Os tratamentos 1, 2 e 3, proporcionaram 3084, 3108 e 3084kcal/kg de energia metabolizável, e 56.69% de CC, 56.69% de ND e 55.00% de ND, respectivamente. Os tratamentos 4, 5 e 6, proporcionaram 2852, 2874 e 2852kcal/kg de energia metabolizável, e 55.20% de CC, 55.20% de ND e 54.35% de ND, respectivamente. No segundo ensaio, 960 frangos foram ditribuídos por 4 tratamentos com 3084, 2852, 2874 e 2852kcal/kg de energia metabolizável. Ambos os estudos não manifestaram diferenças significativas na performance de crescimento relativamente ao tipo de milho usado.

Palavras Chave: Milho Nutridense; Frangos; Performance; Digestibilidade

Summary

One digestibility and two performance experiments were conducted with broilers to compare the feeding value of conventional corn (CC) with Nutridense corn (ND).

In experiment 1, 288 chicks were assigned to 24 experimental pens consisting of two treatments with an inclusion of 92.25% CC (treatment 1) and ND (treatment 2). At 18 days of age, birds were measured for energy and amino acids digestibility. Also, mature roosters were used for true amino acid and energy digestibility. Results in this experiment indicated a higher metabolizable energy value of ND over CC. However, for total digestible amino acids, ND registered no significant differences over CC.

In experiment 2, for trial 1, 384 birds were assigned into 6 dietary treatments. Treatments 1, 2 and 3 provided 3084, 3108 and 3084 kcal/kg, and an inclusion of 56.69% CC, 56.69% ND and 55.00% ND, respectively. Treatments 4, 5 and 6 provided 2852, 2874 and 2852 kcal/kg, and an inclusion of 55.20% CC, 55.20% ND and 54.35% ND, respectively. For trial 2, 960 birds, were distributed through 4 dietary treatments that provided 3084, 2852, 2874 and 2852 kcal/kg. For both trials there were no significant differences in growth performance due to the type of corn.

Keywords: Nutridense Corn; Broilers; Performance; Digestibility

Resumo Alargado

Num mundo industrial, esforços para aumentar a eficiência estão ainda a ser aperfeiçoados. A carne de frango continua a ser a mais saudável e mais barata na maioria dos países, devendo-se a isto a principal razão do seu êxito mundial. Assim, na indústria de frangos de carne, os produtores apontam para uma redução dos seus custos valorizando a investigação a nível genético e nutricional.

Muitos investigadores afirmam que os frangos de carne alimentam-se de forma a preencher as suas necessidades energéticas. Deste modo, a sua alimentação torna-se o factor mais dispendioso para os seus produtores. Assim, a energia é uma variável a ter em em grande consideração na formulação de dietas.

Com esta preocupação em mente, investigadores desenvolveram vários procedimentos experimentais para medir a energia metabolizável nos alimentos e nas dietas para frangos. Como resultado, a energia metabolizável tornou-se a medida mais usada para calcular a disponibilidade de energia na alimentação de frangos. A energia metabolizável é determinada através de variados procedimentos experimentais, relacionando a entrada de alimento com a produção de dejectos pelo animal. Dois destes procedimentos experimentais, foram eleitos e amplamente usados para formulação de rações. São eles o cálculo da energia metabolizável aparente e verdadeira, com correcção para o nível de azoto no animal. A energia metabolizável verdadeira tem em conta as perdas de energia a nível endógeno e urinário.

Com processos experimentais eficientes para medir a energia nos alimentos através dos animais, os produtores agrícolas em conjunto com os investigadores começaram a desenvolver novas variedades de ingredientes contendo nutrientes que fornecessem eficientemente proteína e/ou energia. Neste contexto, o milho é o ingrediente mais usado para fornecimento de energia na alimentação das aves. Como resultado, a selecção genética desenvolveu novas variedades de grãos de cereais, principalmente o milho, com características nutritivas aperfeiçoadas, resultando em estirpes de milho com concentrações superiores em nutrientes como o óleo de milho e aminoácidos (Hastad et al., 2005). Uma tal variedade de milho híbrido seleccionada é conhecida por milho "Nutridense" e tem no mínimo mais 1 % de óleo e mais 1 a 2 % de proteína comparado com o milho convencional (CC), contendo maiores quantidades de aminoácidos essenciais, incluindo lisina, aminoácidos sulfurados, treonina e triptofano (Akay et al., 2001).

Com o intuito de comparar uma nova variedade de milho híbrido geneticamente seleccionado, "Nutridense" (ND), com o milho convencional usado em dietas “standard”, em termos de digestibilidade e performance, realizou-se um ensaio experimental de digestibilidade e dois de performance, com frangos de carne.

No estudo da digestibilidade, 288 pintos foram seleccionados e divididos por 24 gaiolas que se dividiam, por sua vez, em dois tratamentos com uma inclusão de 92,25 % de CC (tratamento 1) e de ND (tratamento 2). Aos 18 dias de idade, foi medida a digestibilidade da energia ao nível do íleo e das fezes e dos aminoácidos ao nível das fezes. Galos adultos foram também usados para a medição da digestibilidade verdadeira da energia e dos aminoácidos.

Os resultados obtidos neste ensaio, indicaram que a energia metabolizável do ND é superior à do CC. No entanto, para a digestibilidade dos aminoácidos, o ND não mostrou diferenças significativas perante o CC.

Nos estudos de performance, o primeiro ensaio foi realizado dos 0 aos 20 dias de idade, com 384 frangos seleccionados e divididos por 6 tratamentos diferentes. Os tratamentos 1, 2 e 3, proporcionaram 3084, 3108 e 3084 kcal/kg de energia metabolizável, e uma inclusão de 56,69 % de CC, 56,69 % de ND e 55,00 % de ND, respectivamente. Por sua vez, e a um nível energético mais baixo, os tratamentos 4, 5 e 6, proporcionaram 2852, 2874 and 2852 kcal/kg de energia metabolizável, e uma inclusão de 55,20 % de CC, 55,20 % de ND e 54,35 % de ND, respectivamente. Aos 6, 13 e aos 20 dias de idade, foram registados os pesos vivos e o consumo de ração de modo a calcular a eficiência alimentar dos animais. Os resultados neste estudo indicaram que, dos 0 aos 6 dias de idade, a interpretação dos resultados teria demasiados factores a considerar para se fazer um juízo correcto e fiável, em oposição aos intervalos que se seguiram. Assim, os resultados indicaram que não houve diferenças significativas ao nível da performance dos animais, relativamente ao tipo de milho utilizado.

O segundo ensaio, relativo a performance, foi realizado dos 15 aos 33 dias de idade, e com 960 frangos que foram distribuídos por 4 tratamentos com 3084, 2852, 2874 e 2852 kcal/kg de energia metabolizável e com uma inclusão de 56,69 % de CC, 55,02 % de CC, 55,02 % de ND e 54,35 % ND, respectivamente. A eficiência alimentar dos animais foi calculada aos 33 dias de idade.

Os resultados mostraram que os animais com acesso à ração com o nível energético mais alto, obtiveram performances significativamente superiores ($P < 0.05$) para um peso final semelhante aos dos restantes tratamentos em dietas com valores energéticos inferiores. Ainda assim, diferenças significativas resultantes do tipo de milho utilizado, não foram registadas.

Estes resultados indicaram, assim, que performances similares dos frangos, podem ser obtidas quando o CC é substituído pelo ND.

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List of Abbreviations

CC – Conventional corn

ND – Nutridense corn

YDC – Yellow dent corn

HOC – High oil corn

HPC – High protein corn

AME_n – Apparent metabolizable energy corrected for zero nitrogen

TME_n - True metabolizable energy corrected for zero nitrogen

TAA – True amino acid availability

I. Introduction

In an industrial world, efforts to maximize efficiency and efficacy are still being perfected, leading to a broilers' industry that continues to produce the healthiest and least expensive meat in most countries, owing to it the main reason for its success worldwide. Consequently, in broiler chickens' industry, producers are aiming to reduce their costs by relying on research.

It is of common knowledge that broilers, also, eat to meet their energy requirements. Adding to this, feed turns to be the most expensive factor for broilers' producers. Thus, energy is the most important factor in feed formulation. With this preoccupation in mind, researchers developed many experimental procedures to measure the energy in the feed. As a result, metabolizable energy has become the standard measure of energy availability in chickens and most other farm species. Metabolizable energy is determined by various bioassay procedures, whereby feed intake and excreta output are related, and the most widely used ones are apparent metabolizable energy corrected for nitrogen and true metabolizable energy also corrected for nitrogen.

With bioassays to effectively measure energy, researchers started to develop new varieties of ingredients containing nutrients that provided efficiently energy and/or protein. For that matter, yellow dent corn is the most widely used ingredient for energy in poultry feed. As a result, genetic selection has been directed to come up with new varieties of cereal grains, especially corn, with enhanced nutrient profiles for use in livestock diets. Such improvements resulted in corn hybrids with higher concentrations of corn oil and amino acids (Hastad *et al*., 2005). One such variety of corn hybrids is "Nutridense" and contains, at least, more 1 % unit of oil and more 1 to 2 % units of protein content compared with YDC, containing also greater amounts of essential amino acids, including lysine, sulfur amino acids, threonine, and tryptophan (Akay *et al*., 2001).

Several studies have reported better performances or at least similar results in poultry and swine trials, comparing CC with ND. Those studies indicate that using HOC can result in improved broiler performance, if feed is formulated to take advantage of the superior energy content of HOC. Also, the need to supplement rations with concentrated oils or fats could be reduced by using HOC and at the same time still meet the energy requirements of broilers but at a lower cost (Benitez *et al*., 1999).

For the reasons mentioned above, the objective of this study was to compare a new HOC variety genetically selected, "Nutridense", with CC used in standard diets, on the digestibility and the performance of broilers chickens.

II. Literature Review

1. World Food's Situation

World food shortages, as predicted in the early 1970s, have not materialized, and in fact most developed countries are faced with surplus production of many commodities. However, that famine is painfully evident in certain countries and is most often a reflection of economic or political restraint, rather than a shortage of food or animal feed in the world markets. As a result, our current abundance of most feeds and foods should be distributed equally around the population worldwide.

So far, we have been able to meet increased demands for human food through a combination of increased supply and through improved production efficiency. Such improvements in efficiency of production will allow us to gradually upgrade the general nutritional status of the world population as a whole and it is evident that the poultry industry is playing a major role in this important development.

In the past we have had to face the criticism of the manufacture's energy use in animal production and essentially from the point of view of inefficiency of consuming animal vs. vegetable protein. Of the total energy used by most developed countries, less than 4 % is used for food production. During this food production, by far the greatest quantities of energy are used during processing and household preparation to meet the stringent demands of the consumer. Consequently, of the 4 % of energy used by the agrifood business, only 18 % of this is actually used in primary animal production.

Increased human consumption of vegetable protein has failed to materialize, essentially due to excessive energy use, necessary during manufacture, which is a criticism originally aimed at animal production. The production of synthetic meat analogues is thus very energy intensive, and their limited impact over the last decade attests to problems with economic viability and/or consumer acceptance. With the economy of many third world countries improving, there appears to be increased demand for animal products and especially meat and eggs. While in the immediate future there will likely be no major increase in production of meat, current trends suggest that poultry is assuming a larger proportion of this global commodity.

Poultry meat and, to a lesser extent, eggs are ideally suited to meet the increased demands for animal products with improved efficiency of production. The success of the broiler chicken in North America is now being mirrored around the world due to four major factors: ease of establishing integrated operations; economically competitive price of poultry vs. red meats; adaptability for further processing; meat composition in relation to human health (Leeson and Summers, 1997).

2. *Broiler Chicken*

Chicken continues to be the least expensive meat in most countries, and this undoubtedly has been the main reason for its success worldwide. This competitive situation has occurred due to continued improvements in efficiency of production that often needs acceptance of new ideas and innovations by producers and agribusiness organizations. On the other hand, production systems for competitive meat products have shown little change over the last two decades (Leeson and Summers, 1997).

At the same time, genetic selection, heterosis, nutrition, and improvements in husbandry and health, have contributed to an escalating growth rate of meat type chickens. During the late 1940s, twelve weeks were required for broilers to reach a live body weight of 1800 g. Four decades later this period had been reduced by half (Gyles, 1989), with the reduction of essentially one day per year to reach this weight (Nitsan et al., 1991a), showing evidence of abatement at the present time. Today, a broiler reaches 2 kg in 5 weeks.

Increased growth rate of the broiler chicken is achieved by concomitant increase in feed intake. Few animals are able to consume feed at the rate exhibited by the broiler chicken, which can have a daily intake as high as 10 % of body weight on a dry matter basis. Nutritionists are faced with the problem of accommodating this voracious appetite with modification to the diet nutrient profile so as to achieve desired growth, carcass characteristics (Leeson et al., 1996) and improvements in health.

It is generally assumed that nutrient digestibility does not change with increasing age. However, reports have shown that early growth of the small intestine is very rapid and exceeds that of body weight until 6 or 7 days of age for both chicks (Nitsan et al., 1991b; Obst and Diamond, 1992) and poults (Sell et al., 1991). In addition, digestive enzyme concentrations have been reported to increase through the first 14 days of age (Nitsan et al., 1991b; Sell et al., 1991). Uni et al. (1995) reported that villus height and width increased 25 to 100% in all segments of the small intestine between 4 and 10 days of age. Thus, during this development and maturation of the digestive system in young poultry, dietary nutrients may be poorly utilized, especially during the first 7 to 10 days posthatching. A few studies have shown that metabolizable energy values of diets are lowest between 4 and 7 days posthatching in chicks (Zelenka, 1968) and turkeys (Sell, 1996) and then increase with age. In studies with birds over 2 weeks of age, some authors have found that metabolizable energy values were not affected by age (Siregar and Farrell, 1980), whereas others have reported a decrease in metabolizable energy with increasing age (Bartov, 1988). Batal and Parsons (2002), reported that metabolizable energy corrected for nitrogen and amino acid digestibility of a corn-soybean meal and corn-canola meal diets, increased with age for young chicks.

3. Corn

The most important cost in poultry production is feed, and the typical chicken diets used in the United States are based on corn as the main source of energy and on soybean meal as the main source of protein (Lordelo, 2000) which together often account for 70-80 % of the components of a feed. Other ingredients may vary depending upon local availability but there are few viable choices. Wheat and by products such as wheat shorts together with sorghum are the other major cereal choices, and most diets will contain some supplemental fat of either animal or vegetable origin. Alternates to soybean meal are rapeseed meal, sunflower meal, corn gluten meal and cottonseed meal. Many diets today, in the United States, contain some meat meal, because currently it is inexpensive due to its exclusion from ruminant diets. Poultry by-product meal is another animal protein available in regions where there is a major broiler industry. Therefore, the United States have just over ten ingredients that constitute the major portion of most poultry diets. The largest producers of these ingredients are North America, Brazil and Asia.

In formulating diets, it is essential to know the bird's nutrient requirements, and consequently the concentration of these nutrients in the various ingredients. Yellow dent corn (YDC) is the major cereal used in most poultry diets. It is very high in energy, and so usually provides the single largest supply of energy in a diet. One source of the energy value of corn is the starchy endosperm. Starch is a carbohydrate reserve that is stored mainly in grains and other seeds. Like cellulose, starch is a polymer of glucose with the only difference being that in starch the glucose molecules are linked together by a 1,4' α-linkage instead of the 1,4' β-linkage of cellulose. Starch occurs in cereal grains and other feedstuffs as small granules, which may be spherical, oval, lens-shaped or irregular depending upon the source. Cereal starch is arranged in concentric layers, potato starch in eccentric layers. Microscopists can identify the source of starch by examination of granule shape and arrangement. Within the natural feedstuffs, starch exists in a hydrated polymeric form arranged in a crystalline lattice. Its composition corresponds to the empirical formula $(C_6H_{10}O_5 \bullet H_2O)_n$. When the water of hydration is driven off by heat, the structure becomes amorphous.

Isolated starch granules contain up to 0.05 % nitrogen, some fatty acids and some phosphate. The nitrogenous matter can be removed by treatment with hydrochloric acid; the fatty acids and some of their phosphatide phosphorus may be extracted with alkali. These nitrogenous and phospholipid materials in starch have complicated the interpretation of experiments for chickens where starch is used in purified basal diets as the carbohydrate source. Glucose and sucrose, produced commercially in almost pure form, are better sources of carbohydrate for this type of experimental work.

When starch is treated with hot water it separates into two fractions; the more soluble component, amylose, is dissolved, while amylopectin remains as the insoluble fraction. In natural feedstuffs amylose usually represents about 10 to 20 % and amylopectin 80 to 90 % of the total starch. Amylose, upon treatment with iodine, gives a blue color while amylopectin produces a violet or red-violet color. Like cellulose, amylose has a straight, long-chain molecular structure. Amylopectin is made out of the same glucose units as amylose but differs physically by having a branched-chain molecular structure. The main portions of its chains are joined by 1,4’ α-glucose linkages which yield maltose as the first digestion product. The branches are joined by 1,6’ α-linkages which yield iso-maltose residues prior to final breakdown to D-glucose.

All animals contain an abundance of α-amylases. In mammals, these enter the gastro-intestinal tract via the saliva and as pancreatic secretions. Although the saliva and crop of the chicken contain some α-amylases, little starch digestion has been demonstrated in the crop. In the small intestine of chickens, quite good digestion, even of the raw starches of corn, wheat and potatoes, takes place through the action of the pancreatic amylases. In its natural state, starch exists as an insoluble granular form, which physically resists digestion. The cooking of foods markedly aids digestion of starch by breaking down and solubilizing the starch granules. These granules also can be broken down by physical disruption, aided by soaking in water. Thus, in the chicken, it appears likely that good starch digestion is partially due to the initial soaking of the feed in the crop and subsequent grinding action of the gizzard which precedes action of the pancreatic amylases. Precooking of feedstuffs may increase their metabolizable energy values, as may the steam and pressure used in pelleting of feeds.

Another source of the energy value of the corn comes from the germ which contains most of the oil. Most corn contains 3-4 % oil, although newer varieties are now available which contain up to 6-8 % oil, and so contribute to proportionally more energy. The protein in corn is mainly as prolamin, specifically as zein (class of prolamin protein found in maize), and as such, its amino acid profile is not ideal for poultry. This balance of amino acids and their availability is most important when low protein diets are formulated because under these conditions the corn prolamin can contribute up to 50-60 % of the diet protein (Leeson and Summers, 2001).

4. Nutridense Corn

Genetic selection and modification have provided new varieties of cereal grains that have enhanced nutrient profiles for use in livestock diets. These improvements have resulted in corn varieties with higher concentrations of nutrients such as oil and amino acids (Hastad et al., 2005). High oil corn has a larger germ in the kernel than YDC, and the protein content of the germ is normally higher than the rest of the kernel (Parsons et al., 1998). Therefore, HOC has a higher level of crude protein content than YDC.

It is possible that corn germ protein may be more highly digestible for poultry than the other protein in corn; however, to our knowledge, no research has been published on this topic (Mateos *et al*., 1982; Sell *et al*., 1983). It is also possible that the higher oil content of HOC may contribute to higher amino acid availability. It has been reported that supplemental dietary fat may increase intestinal retention time of feed and results in a more complete digestion of non-lipid dietary constituents (Mateos *et al*., 1982; Sell *et al*., 1983), such as amino acids. Also, the nutritional value of HOC for poultry has been evaluated by Dale and Whittle (1991), who reported that the metabolizable energy content was increased by 37.0 kcal/kg for each 1 % increase in oil content.

A new corn hybrid, "Nutridense" (ND), has a minimum 1 % unit higher oil and 1 to 2 % units higher protein content compared with YDC and contains greater amounts of essential amino acids, including lysine, sulfur amino acids, threonine, and tryptophan (Akay et al., 2001). Specifically, it contains approximately 30 % more lysine, 50 % more total sulfur-containing amino acids, 18 % more threonine, and 6 % more metabolizable energy than normal corn (Hastad et al., 2005).

Research has been done in other species to study the digestibility of ND and the effect on the performance of animals. High yielding dairy cows may benefit from the dietary inclusion of ND because of its higher energy concentration compared with YDC. Also, the composition of protein in ND is derived from the amino acid contributions of the germ and is highly degradable in the rumen (Jerry Weigel, 1998, personal communication).

Previous studies in pigs have demonstrated effective utilization of these corn varieties (Adams and Jensen, 1987; Han et al., 1987; Adeola and Bajjalieh, 1997). Diets using corn with enhanced nutritional traits can improve feed efficiency, decrease nutrient waste, and potentially be cost-effective to swine producers (Hastad et al., 2005). Nursery trials conducted with HOC by Bergstrom *et al.* (1997) and De-Camp *et al.* (1998) also showed improvements in feed conversion. In growing-finishing pigs, Kendall *et al.* (1999) showed a similar improvement in feed efficiency when YDC was replaced with a HOC hybrid (Hastad *et al*., 2005).

Mireles *et al*. (1996) found that complete substitution of CC (3.6% crude fat) with #80 HOC in isonitrogenous, isocaloric diets produced significantly better feed conversions with similar carcass yields. Han *et al*. (1987) showed that HOC varieties were superior to CC for poultry, due to the fact that these varieties contained higher concentrations of metabolizable energy, protein, lysine, and carotenoids than CC, thus improving growth and feed efficiency of broilers. In addition, Adams *et al*. (1994) found that substituting CC for HOC improved performance when diets were formulated to take advantage of the superior energy and amino acid content of HOC. At similar levels of dietary energy, the performance of birds was similar for all types of corn (Benitez *et al*., 1999).

On the other hand, Han *et al.* (1987) reported improvements in growth rate and feed conversion resulted from the increased dietary energy obtained when HOC replaced YDC on a weight/weight basis. Also, Benitez *et al*., (1999) reported that using the latest varieties of HOC in place of CC in isonitrogenous diets with similar energy levels produced equivalent results in broilers. Bartov and Bar-Zur (1995) found no differences in weight gain or feed intake in broilers when imported corn, Israeli HOC, or CC supplemented with corn oil to equalize fat and protein content, were compared. Mello *et al*. (1997_a) found that body weight and feed conversion were unaffected in 6-week-old broilers fed isocaloric and isonitrogenous diets containing CC, HOC, or high protein corn (HPC). Stillborn *et al*. (1997) also found that HOC and CC produced similar results when energy and amino acid levels were similar in both diets. In another study, Mello *et al*. (1997_b) found that CC, HOC, and HPC formulated in isocaloric, isonitrogenous diets with similar amino acid profiles did not affect 6-week body weight, weight gain, mortality, or feed conversion of broilers, although feed intake for birds fed CC was significantly ($P < 0.05$) greater than that of the others. Thus, these three varieties of corn produced comparable results in performance (Benitez *et al.*, 1999).

Results from these previous studies indicate that using HOC can result in improved broiler performance, if feed is formulated to take advantage of the superior energy content of HOC. Also, the need to supplement rations with concentrated oils or fats could be reduced by using HOC and at the same time still meet the energy requirements of broilers but at a lower cost (Benitez *et al*., 1999).

5. Energy

The term energy is a combination of two Greek words: *en*, meaning “in” and *ergon*, meaning work. The energy required by chickens for growth of body tissues, production of eggs, carrying out of vital physical activities and maintenance of normal body temperature, is derived from carbohydrates, fats and proteins in the diet. The dietary energy consumed by an animal can be used in three different ways: it can supply the energy for activity, it can be converted to heat, or it can be stored as body tissue. Dietary energy exceeding that needed for normal growth and metabolism of the bird is usually stored as fat. Excess available energy cannot be excreted by the animal body. Optimum nutrient utilization by the chicken is achieved when the diet contains the proportion of energy to other nutrients needed to produce the desired growth, egg production or body composition.

Energy is described by Kleiber (1961) as the fire of life. The major portion of all feed consumed by an animal is used for energy since both anabolic and catabolic reactions create a demand for energy. In short term, gastric digestion has some influence on feed intake, although in long term (days) there is involvement of blood glucose. Regions of the hypothalamus are influenced by both high and low levels of glucose, and so this association can serve as a basis for feed intake regulation. In the longer term (weeks), levels of certain amino acids in the blood can also influence feed intake.

Broiler chickens in general have a remarkable ability to control their energy intake when confronted with diets or diet components of varying energy concentration. This important mechanism is the basis for many decisions made during feed formulation.

While the taste of food may have a large influence on the amount of energy consumed by man and certain other animals, taste appears to play a relatively minor role in the feed consumption by the chicken. Energy level of the diet appears to be an important factor determining feed intake. When an animal such as the growing or laying chicken is given a diet adequate in all nutrients, the animal will consume the diet to obtain a remarkably constant feed intake of available energy per day. The absolute amount consumed depends upon the needs of the animal which vary depending upon its size, its activity, the environmental temperature, whether it is growing, simply maintaining itself or laying eggs. It is of utmost importance, therefore, that we know the energy requirements of chickens during each stage of their growth and development and that we have precise information concerning the available energy values of the feedstuffs used to formulate their diets. With this information, it is possible to closely predict the feed consumption of any flock of chickens in a particular environment and thus to determine the levels of protein, amino acids, vitamins and mineral such that all nutrients will be provided in adequate amounts for optimum daily growth and performance.

Poultry producers often think of energy in terms of those feedstuffs which have been shown to be particularly rich sources, such as corn, wheat, sorghum grains, and animal and vegetable fat oils. However it must be remembered that all organic components of a diet provide energy. In high protein diets, ingredients such as soybean meal can provide substantial proportions of total energy.

The nutritionist must consider energy in terms of the digestible starch, sugars, fats and proteins in the feedstuffs and how processing of the ingredients, balancing of the diet and addition of special supplements such as antioxidants or enzymes may aid in providing the birds with the maximum amount of available energy.

All materials containing carbon and hydrogen in forms that can be oxidized to carbon dioxide and water represent potential energy for animals. The amount of heat produced when a feed is burned completely in the presence of oxygen can be measured in a bomb calorimeter and is termed the gross energy of the food. The percentage of gross energy that can be taken into the animal body and used to support the metabolic processes depends upon the ability of the animal to digest the feedstuffs. Digestion represents the physical and chemical processes which take place in the gastrointestinal tract and result in breaking down the complex chemical compounds in feeds into the smaller molecules that can be absorbed and used by the animal. This absorbed energy is termed digestible energy. Further losses of energy occur in the urine in the form of nitrogenous wastes and other compounds not oxidized by the animal body. When the digestible energy is corrected for these losses the resultant energy it is called metabolizable energy value of the food or feedstuff. During metabolism of the nutrient further losses of energy occur (heat increment). The remaining energy of feed that is available for the animal to use for maintenance and productive purposes is called net energy.

Gross energy is determined by adiabatic bomb calorimetry and is the only simple lab assay for energy. In nutritional studies, gross energy has no meaningful value, other than providing a starting point for other systems of evaluation. Requesting a gross energy value of a feed, from an analytical service, is totally wasteful and a misleading exercise. At best, the gross energy will indicate the balance of organic vs. inorganic components.

Other measures of energy require the use of live birds involving a classical bioassay procedure.

5.1. Metabolizable Energy

It is very difficult to separate the feces and the urine of the bird without resorting to surgical modification that exteriorizes the ureters. This seems an unnecessary procedure, since collection of feces and urine together (as excreta) leads directly to estimates of metabolizable energy.

Metabolizable energy has become the standard measure of energy availability in chickens and most other farm species. Metabolizable energy is determined by various bioassay procedures whereby feed intake and excreta output are related over a 2 to 5 day test period. Apparent metabolizable energy is most commonly determined through actual measurement of feed intake and excreta output, or by determining the ratio of dry matter intake to output through use of an inert dietary marker, such as chromic oxide (Cr_2O_3). A number of potential problems arise with the use of markers (Kane *et al*., 1950; Vohra and Kratzer, 1967; Duke *et al*., 1968; Vohra, 1972), and thus the latter method often leads to more variation in final determined metabolizable energy values (Potter, 1972). Inert digestibility markers are routinely used to estimate the digestibility of dietary nutrients. The ratio of the marker in the diet to the amount of marker in excreta or ileal digesta indicates the digestibility of the diet by the bird (and gut microflora). The classical use of digestive markers was reviewed by Kotb and Luckey (1972) and Han *et al*. (1976). Oberleas *et al*. (1990) observed that the use of chromium as an inert digestibility marker may be negated, particularly for estimating rates of passage, as it was carried more readily by the fluid rather than the solid portion of the digesta (Scott and Boldaji, 1997). In the 1960s, the use of chromic oxide as a marker to determine metabolizable energy content, digestibility of feeds, and feed ingredients was the method commonly used in poultry (Vohra, 1966). However, problems, such as the reproducibility of the assay for chromium oxide (Halloran, 1972) and hazardous effects because of its potential carcinogenicity (Peddie et al., 1982), has led to the acceptance of the total collection method as the most applicable method (Sales and Janssens, 2003). Tillman and Waldroup (1988) compared total collection and the use of insoluble ash (0.25 % sand) as a marker for measuring apparent metabolizable energy of feedstuffs for broiler chickens. Total collections required periods of feed withholding prior to and at the end of the collection period, whereas the use of a marker allowed *ad libitum* feed access and a shorter collection period (Scott and Boldaji, 1997). Also, as reported by Sibbald (1987), who compared the total collection method, the use of markers to determine metabolizable energy and digestibility values avoids errors associated with inaccurate measurement of feed intake, excreta output, and contamination of excreta (Sales and Janssens, 2003).

When the metabolizable value of an ingredient is to be determined, two or more diets must be used, since feeding an ingredient by itself can cause palatability problems and fails to accommodate potential synergism between nutrients. The two methods most frequently used in substituting the test ingredient into a control basal diet are those described by Anderson *et al*. (1958) and Sibbald and Slinger (1963). In the former method the test ingredient is substituted for glucose, but in the latter method the test ingredient is substituted for all the energy-yielding ingredients of the basal diet. Anderson *et al*. (1958) proposed that the value of 3.65 kcal/g be used as the standard for glucose. The basal diet used by Anderson *et al*. (1958), containing about 50 % glucose and designated as E9, has been used extensively in determinations of metabolizable energy.

In the method of Sibbald and Slinger (1963) the test ingredient is substituted essentially for part of the complete basal diet. However, to avoid mineral and vitamin deficiencies, components of the diet containing these nutrients are left intact. The use of two basal diets of differing protein contents was proposed to maintain the protein contents of substituted diets within an acceptable range. An advantage of the substitution method of Sibbald and Slinger (1963) is that the metabolizable energy value of the reference basal diet is necessarily determined in each metabolizable energy assay. Although samples of glucose may vary under different dietary conditions, and its metabolizable energy value should be determined under experimental conditions used (Mateos and Sell, 1980).

The test ingredient may be substituted at one or more levels. Regardless of the basal diet used, the accuracy of the metabolizable energy value obtained depends to some extent on the proportions of the test ingredient substituted into test diets. In extrapolating to calculate the metabolizable energy value of the test ingredient, the error of determination of the test ingredient is therefore multiplied by a factor of 100 divided by percentage of substitution. Therefore the highest proportion of the test ingredient possible in the test diet should be used. Usually, this amount is determined by nutrient balance and palatability.

Potter *et al*. (1960) proposed a linear regression procedure for the calculation of metabolizable energy values for ingredients substituted at several levels. The ingredient metabolizable energy value is derived by extrapolation to 100 percent inclusion from a regression equation relating test diets. As for most other methods of metabolizable energy determination, a criticism of the regression method is that the extrapolation is beyond the range of experimental data. Sibbald and Slinger (1962) pointed out that this general criticism is of little significance as long as the range of inclusion level used is within that normally encountered under practical conditions because it is the application of ingredient metabolizable energy values in commercial dietary formulation that is of interest.

5.2. True Metabolizable Energy

True metabolizable energy was described as an estimate of metabolizable energy in which correction is made for metabolic fecal and endogenous urinary energy (National Research Council, 1981). These energy components of excreta are not directly of dietary origin and, as suggested by Sibbald (1980), correction for their excretion in bioassays leads to true metabolizable energy. It should be noted that metabolizable energy as determined using the procedure of Anderson *et al*. (1958) inherently corrects for metabolic fecal and endogenous urinary energy excretion, whereas the method of Sibbald (1976) for determining metabolizable energy does not (National Research Council, 1994).

The true metabolizable energy method of Sibbald (1976) involves fasting birds for 24 hours and then force-feeding a relatively small amount of the test material. Excreta collection is made after 24 hours from the time the birds are force-fed (Muztar and Slinger, 1981). Excreta is dried and then analyzed for gross energy. True metabolizable energy is calculated as the difference between ingested and excreted energy, corrected for endogenous excretion (Dale and Fuller, 1984). The assay is also much faster and more economical to conduct than are the traditional metabolizable energy procedures (Hill *et al*., 1960; Potter and Matterson, 1960; Sibbald and Slinger, 1963). The correction for metabolic fecal energy plus endogenous urinary energy losses are applied using values measured with unfed birds of similar body weight to the fed birds (Muztar and Slinger, 1981). Also, the true metabolizable energy assay methodology has been extended to permit the measurement of bioavailable amino acids in feedingstuffs (Likuski and Dorrell, 1978; Sibbald, 1979).

The true metabolizable energy procedure, however, has been subjected to criticism. True metabolizable energy determinations assume that fecal metabolic and urinary endogenous energy excretions are constant, irrespective of feed intake. However, data have been presented showing that metabolic and endogenous energy excretions are influenced by amount and nature of materials passing through the gastrointestinal tract (Farrel, 1981; Farrel *et al*., 1991; Tenesaca and Sell, 1981; Härtel, 1986). Another criticism is that ingredients are often force-fed alone, thereby preventing synergistic or antagonistic effects between or among ingredients on energy utilization. Synergism is known to occur between fatty acids (Young, 1961; Artman, 1964; Leeson and Summers, 1976) and there is evidence for synergism between proteins concentrates (Woodham and Deans, 1977). A third criticism of the true metabolizable energy method relates to the imposition of 48 hour periods of feed deprivation, which would result in abnormal physiological status of the bird.

5.3. Nitrogen Correction

Metabolizable energy values are commonly corrected for nitrogen retention to convert all data to a basis of nitrogen equilibrium for comparative purposes (Spratt and Leeson, 1987; Sibbald, 1989; Bourdillon et al., 1990a,b; Farrell et al., 1991, 1997; Emmans, 1994; Fisher, 2000; Leeson and Summers, 2001; MacLeod, 2002). The metabolizable energy values corrected for nitrogen retention reported for feedstuffs are usually determined with adult roosters and this information is used as the basis to formulate diets for different types of birds, including broilers (Dale and Fuller, 1984; Bourdillon et al., 1990a,b; Farrell et al., 1991). Nitrogen correction is used to account for the variable effects of growth and body protein accretion among birds, nitrogen retention as eggs, or both (Hill and Anderson, 1958; Miller, 1974; Sibbald and Wolynetz, 1985; Bourdillon et al., 1990b; McNab, 2000). Nitrogen correction is also important if comparisons are to be made across breeds that inherently retain nitrogen at different rates. Many studies have indicated that metabolizable energy values corrected for nitrogen retention for broilers are lower than estimates derived from adult Leghorn birds (Mollah et al., 1983; Härtel, 1986; Bourdillon et al., 1990b; Carré et al., 1995; Farrell et al., 1997).

The correction for nitrogen retention is made under the assumption that the oxidation of protein tissue will yield uric acid, which has a gross energy per gram of nitrogen of 8.22 kcal (Hill and Anderson, 1958; 2.74 kcal/g of uric acid at 33.33 % nitrogen). The correction value is added to the excreta energy for each gram of nitrogen retained (e.g., if the nitrogen had not been retained, it would have been excreted as uric acid). This removes the effect of differences in growth, inherent across birds in any assay. In his extensive review of metabolizable energy, Sibbald (1982) reported alternate values (8.73 kcal/g of nitrogen) as being more representative of the combustion energy of the total mixture of endogenous nitrogenous constituents of chicken urine. Nitrogen correction has also been used to decrease variability of estimates of metabolizable energy of ingredients varying in protein content (Leeson et al., 1977). It is generally accepted that correction to zero nitrogen is essential in comparison of metabolizable energy values across species that inherently have differential rates of growth and nitrogen retention. Likewise, nitrogen correction seems essential for comparison of the metabolizable energy values determined with juvenile versus mature birds, because the former are growing and the latter are usually at zero nitrogen retention. However nitrogen retention is expected to more greatly influence the metabolizable energy values of ingredients such as soybean meal compared with corn because of associated higher protein accretion. A similar effect is expected from diets higher in crude protein, such as starter diets. The nitrogen correction therefore heavily penalizes high-protein ingredients (or diets) and so their metabolizable energy values corrected for nitrogen retention is correspondingly reduced. If birds were at similar rates of nitrogen retention, then theoretically the nitrogen correction is unwarranted, because it biases certain ingredients and diets. It is proposed that such a situation applies with the modern broiler. Nitrogen retention in fast-growing broilers is expected to vary little from 0 to 49 days as compared with adult roosters. Therefore, metabolizable energy may be a more appropriate measure of energy used for a commercial broiler nutritionist, because that comparison with other avian species, age, or both, is not a major consideration (Lopez and Leeson, 2007).

Also, regarding Lopez and Leeson (2007), the nitrogen correction imposes a 4 to 5 % reduction on the apparent metabolizable energy value of a single diet. When a commercial series of diets was used, the correction declined from 5.3 % at 7 days to 3.8 % at 49 days, reflecting the decline in protein content of the diet and the decline in nitrogen retention over time. This information suggests that if apparent metabolizable energy rather than apparent metabolizable energy corrected for nitrogen retention values are accepted, then roosters provide a good estimate of values applicable for broiler nutrition, because values are little different. Because there was less variance in energy values expressed as apparent metabolizable energy corrected for nitrogen retention rather than apparent metabolizable energy, it appears that there was sufficient bird-to-bird variation in growth, nitrogen retention retention, or both, to warrant the use of the correction factor.

6. Net Energy

Metabolizable energy provides a useful measure of the gross energy available for production. Unfortunately such retained energy is not used 100 % efficiently for growth, egg production, etc. During these metabolic processes, some 15 % of energy will be “wasted” as heat, and this is commonly referred to as heat increment or specific dynamic action. Different nutrients are utilized with varying efficiencies, and so net energy becomes a variable dependent on the bird’s stage of growth, production or development. It is very difficult to measure net energy, because the necessary correction factor, namely heat increment, is difficult to quantify.

A measure of heat output can be obtained from estimates of respiratory quotient, which is an estimate of volume of carbon dioxide produced, divided by the volume of oxygen consumed. Respiratory quotient is usually between 0.7-1.0. When fats are preferentially oxidized, respiratory quotient is 0.7 and with carbohydrate the value is 1.0. Because no one nutrient is ever catabolized independently of others, then the composite respiratory quotient will fall somewhere within these boundaries. Respiratory quotients outside this range sometimes occur with very high values resulting from net synthesis of fat from carbohydrate. Low respiratory quotients can result from synthesis of carbohydrate from fat, and also from the catabolism of proteins. When proteins are catabolized then lower respiratory quotients occur in birds than in mammals which is related to uric acid vs. urea formation. By measuring respiratory quotients at variable levels of feed intake, an estimate of heat increment can be determined. Subtracting this value from apparent metabolizable energy, it produces an estimate of total net energy. This value can be further subdivided into net energy needs for production versus maintenance. The net energy used for production is sometimes referred to as productive energy (Leeson and Summers, 2001).

The net energy for production vs. maintenance can also be ascertained by direct estimates of energy deposited in products. The classical work of Fraps (1946) involved the tedious challenge of estimating “productive energy” of feeds by comparative slaughter techniques. The net energy system is by far the most accurate and applicable measure of energy utilization in animals. Unfortunately it is very difficult to measure directly, and is a value that represents energy yield for a particular class of bird for a given production of body mass, eggs, among other factors. In reality net energy values vary with age of bird, species and level of production, and this poses a logistical problem during formulation. There is current interest in net energy and especially where energy systems are modeled. Unfortunately many such values are based on apparent metabolizable energy with appropriate correction or modifier values, and so are of limited value but for practical formulation, apparent metabolizable energy or true metabolizable energy values are used.

Nearly all net energy systems use apparent metabolizable energy as a starting point in some way and most assume linearity in efficiency of converting apparent metabolizable energy into net energy. In reality the partition of metabolized energy into maintenance, activity and fat and protein accretion vary with age, and so prediction coefficients need to accommodate this complexity. Pirgozlieve and Rose (1999) suggest a linear relationship between apparent metabolizable energy and net energy for production, with 69 % conversion efficiency. Although some 93 % of variance was accounted for in this prediction, apparent metabolizable energy tends to overestimate net energy for production for high protein feedstuffs of animal origin. A potentially confounding factor in prediction of net energy for production is the energy cost of protein deposition. Many years ago Kielanowski (1965) showed that the determined cost of protein deposition was five to six times higher than estimates based on stoichiometry of ATP use. Because protein synthesis far exceeds protein deposition in most birds, the logical explanation for discrepancies of energy cost is protein turnover. While protein turnover can account for about 50 % of the discrepancy in determined vs. calculated cost of protein deposition, another explanation is that many ATP dependent biochemical pathways are stimulated when protein deposition occurs.

Net energy systems are therefore fraught with complexity especially considering the vast range of ingredients and feeding situations now common in poultry nutrition. However, we cannot dismiss this important concept and as specialization continues in the industry, the potential for net energy systems is more appealing.

DeGroote (1974), proposed a method for calculating net energy from determined metabolizable energy values. The metabolic efficiency of utilization of metabolizable energy from protein, fat and carbohydrate is known to differ. Metabolizable energy for carbohydrates has a net availability of around 75 %, protein 60 % and fat 90 %. Thus, the net energy values of diets high in fat may be underestimated compared to diets high in carbohydrates unless some correction factor is applied to the metabolizable energy values. DeGroote (1974) proposed a method whereby the percentage of dietary protein, fat and carbohydrate is multiplied by their appropriate efficiency factor (60, 90 and 75). Therefore, when the metabolizable energy value of an ingredient is multiplied by the appropriate efficiency values a net energy value is obtained. DeGroote (1974) claimed that this method was superior to the metabolizable energy system because it allows a more accurate energy evaluation of the feed ingredients and thus a better prediction of gains and feed conversions expected from different diets. Any error inherent in metabolizable energy estimate obviously influences the net energy estimate (Leeson and Summers, 2001).

Prior to the mid 1950's "productive energy values" was the primary measure of energy content of poultry feedstuffs. Fraps (1946) at Texas A & M University, published an extensive set of productive energy values for feed ingredients.

Emmans (1994) suggested "effective energy" as a system for defining feed ingredients and diets. This system is analogous to a productive or net energy system because it attempts to categorize heat increment. Unlike the classical theories of Armsby and co-workers (1903), the effective energy system takes into account differential heat increments dependent on the catabolism of proteins vs. lipids in the body, and the variable efficiency of utilization and deposition of body lipids dependent upon whether or not they are derived from dietary lipids or synthesized from non-lipid material.

7. The Objective

Many studies were performed in broilers and pigs, showing that HOCs, as ND, had better or, at least, similar results than CC.

Because new varieties of HOC are being developed yearly and because earlier studies are limited and somewhat conflicting, the objective of this study was to measure the performance of broilers fed a recent variety of HOC, ND, and compare with CC.

The present research is composed by one digestibility trial to compose and analyze the nutritive characteristics of ND using a variety of methods to calculate the metabolizable energy and the digestible amino acids on juvenile birds and adult roosters; and also two performance trials, conducted to determine if ND could overcome an energetic gap between the diets formulated by evaluating the growing performances of the broilers chickens.

III. Materials and Methods

1. General

Three studies were conducted to assess whether ND is a viable alternative to Conventional corn. These studies were conducted at the University of Georgia poultry Research Center, Poultry Department, and all procedures have been approved by The University of Georgia Institutional Animal Care and Use Committees.

2. Digestibility Trial

2.1. Apparent ileal amino acid digestibility, ileal and excreta nitrogen-corrected apparent metabolizable energy (AME$_n$) determination:

At hatch, 288 birds, Cobb 500 by product male broiler chicks, were obtained from a local hatchery and immediately placed in Petersime battery brooders with raised wire floors. Chicks were maintained on a twenty four hour, constant light schedule in a thermostatically controlled room. Chicks were fed a standard corn-soybean meal starter diet until thirteen days of age. After an overnight fast, chicks were weighed and assigned to treatment groups so that mean initial weights were similar among the treatment groups. On the 14th day, birds were given access to the experimental diets, and on the 18th day, birds were euthanized for ileal content collection. Excreta was collected on the 16th, 17th and 18th day. Feed and water were provided *ad libitum.* Twelve replicates of 12 chicks per replication were assigned to each of the 2 dietary treatments (2 trts x 12 reps x 12 chicks = 288 birds, 24 pens).

Ileal contents and excreta from all treatments were freeze dried and sent to the Experiment Station Chemical Laboratories at the University of Missouri, Columbia, for amino acid analysis. Diets were sent as well. Ileal contents, excreta and the diets were sent to Midwest Valley Testing Laboratories for gross energy and crude protein. Acid-insoluble ash was run on all diets, excreta and ileal contents.

The two diets (Table 1) were formulated to provide 3303 kcal/kg of metabolizable energy with 92.25 % of CC (treatment 1) and ND (treatment 2).

Table 1. Composition and calculated analysis of treatment diets of the digestibility trial

Ingredient	***Treatment***	
	1 - Conventional corn	2 - Nutridense corn
	---------------------------- %	----------------------------
Conventional corn	92.25	-
Nutridense corn	-	92.25
Poultry fat	2.00	2.00
Dicalcium phosphate	1.95	1.95
Limestone	1.47	1.47
Vitamin mix[1]	0.25	0.25
Salt	0.50	0.50
Mineral mix[2]	0.08	0.08
Celite	1.50	1.50
Calculated values		
Crude protein	7.0	7.8
ME[3], kcal/kg	3303	3303
Methionine	0.17	0.18
Lysine	0.22	0.26
Calcium	1.00	1.00
Available Phosphorus	0.45	0.45

[1] Vitamin mix provided the following per kilogram of diet: vitamin A, 5,510 IU; vitamin D3, 1,100 IU; vitamin E, 11 IU; vitamin B12, 0.01 mg; riboflavin, 4.4 mg; niacin, 44.1 mg; D-pantothenic acid, 11.2 mg; choline, 191.3 mg; menadione sodium bisulfate, 3.3 mg; folic acid, 5.5 mg; pyridoxine HCl, 4.7 mg; thiamin, 2.2 mg; D-biotin, 0.11 mg; and ethoxyquin, 125 mg.

[2] Mineral mix provided the following in milligrams per kilogram of diet: Mn, 60; Zn, 50; Fe, 30; I, 1.5; and Se, 0.5.

[3] ME – Metabolizable Energy

2.2. Nitrogen-corrected true metabolizable energy (TME_n) and true amino acids availability (TAA) determination:

2.2.1. True metabolizable energy corrected for nitrogen assay at excreta level:

Conventional Single Comb White Leghorn mature roosters were fasted for 24 hours. Ten roosters were crop intubated with an exact amount of the test feed ingredient (usually 30-35 grams). The excreta samples were pooled for two birds (instead of the standard of pooling all the excreta from the 8 to 10 birds) to allow for replication (5 replications). Also, four additional roosters were crop intubated with a standard corn sample to correct for endogenous losses. Then, the roosters were placed in collection cages and excreta was collected for 48 hours. Then, excreta was dried, weighed, and ground. Excreta and feed samples were analyzed for gross energy, crude protein, fat, fiber, ash, and dry matter (Midwest Valley Testing Laboratories). True metabolizable energy corrected to zero nitrogen was determined based on the gross energy of the test ingredient and excreta adjusted for the total test ingredient intake and excreta output.

$$AME_n\ (\text{Kcal}) = [\text{Feed's Gross Energy (kcal)} \times \text{Feed Intake (g)} - [\text{Excreta's Gross Energy (Kcal)} \times \text{Excreta (g)} + 8.22 \times \text{N retained (g)}\ ]] \ / \ \text{Feed Intake (g)}$$

$$TME_n\ (\text{kcal}) = AME - \text{Endogenous Losses}$$

2.2.2. True ileal amino acid digestibility assay:

Cecectomized Single Comb White Leghorn mature roosters were fasted for 24 hours. Eight to ten roosters were crop intubated with an exact amount of the test feed ingredient (usually 30-35 grams). The excreta samples were pooled for two birds (instead of the standard of pooling all the excreta from the 8 to 10 birds) to allow for replication (4 to 5 replications). Four additional roosters were not crop intubated with the feed sample/test ingredient and were used for endogenous amino acid determination. The roosters were placed in collection cages and excreta was collected for 48 hours. Then, excreta was dried, weighed, and ground. The excreta and feed samples were analyzed for amino acid concentration (Experiment Station Chemical Laboratories at the University of Missouri-Columbia). True amino acid digestibility was determined based on the amino acid concentration of test feed ingredient and excreta adjusted for total sample intake and excreta output.

3. *Performance Trials*

3.1. Trial 1

At hatch, 384 birds, Cobb 500 by product male broiler chicks, were obtained from a local hatchery and immediately placed in Petersime battery brooders. Chicks were maintained on a 24 hour lighting schedule in a thermostatically controlled room. Chicks had *ad libitum* access to feed and water. Feed consumption was constantly measured and bird's weight was measured on days 0, 6, 13 and 20. Each of the 6 experimental diets was replicated with 8 pens each containing 8 chicks (6 trts x 8 reps x 8 birds = 384 birds, 48 pens).

Two groups, one formulated for high and one formulated for low energy, of three diets were formulated to provide a similar nutrients profile but with variable corn sources (Table 2). Treatments 1 through 3 provided 3084, 3108 and 3084 kcal/kg metabolizable energy, respectively. On treatments 2 and 3, ND was used instead of CC. Treatments 4 through 6 provided 2852, 2874 and 2852 kcal/kg of metabolizable energy, respectively. On treatments 5 and 6, CC was replaced by ND. All diets were formulated to meet the nutrient requirements (National Research Council, 1994).

Table 2. Composition and calculated analysis of treatment diets of the trial 1 from the performance study

Ingredients	*Treatment* [1]					
	High Energy			Low Energy		
	1 - CC	2 - ND	3 - ND	4 - CC	5 - ND	6 - ND
	%					
Conventional Corn	56.69	-	-	55.02	-	-
Nutridense Corn	-	56.69	55.00	-	55.02	54.35
Soybean meal	36.96	36.96	36.96	37.24	37.24	37.24
Poultry fat	3.17	3.17	3.17	-	-	-
Sand	-	-	1.69	3.56	3.56	4.23
Defluor. Phosphorus	1.70	1.70	1.70	1.70	1.70	1.70
Limestone	0.48	0.48	0.48	0.48	0.48	0.48
Vitamin mix[2]	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.35	0.35	0.35	0.35	0.35	0.35
DL-methionine	0.28	0.28	0.28	0.28	0.28	0.28
Mineral mix[3]	0.08	0.08	0.08	0.08	0.08	0.08
L-Lys-HCL	0.03	0.03	0.03	0.03	0.03	0.03
L-Thr	0.01	0.01	0.01	0.01	0.01	0.01
Calculated values						
Crude protein	21.5	21.5	21.5	21.5	21.5	21.5
ME[4], kcal/kg	3084	3108	3084	2852	2874	2852
Methionine	0.51	0.51	0.51	0.51	0.51	0.51
Lysine	1.20	1.20	1.20	1.20	1.20	1.20
Calcium	0.90	0.90	0.90	0.90	0.90	0.90
Avail. Phosphorus	0.45	0.45	0.45	0.45	0.45	0.45

[1] CC – conventional corn; ND – Nutridense corn.

[2] Vitamin mix provided the following per kilogram of diet: vitamin A, 5,510 IU; vitamin D3, 1,100 IU; vitamin E, 11 IU; vitamin B12, 0.01 mg; riboflavin, 4.4 mg; niacin, 44.1 mg; D-pantothenic acid, 11.2 mg; choline, 191.3 mg; menadione sodium bisulfate, 3.3 mg; folic acid, 5.5 mg; pyridoxine HCl, 4.7 mg; thiamin, 2.2 mg; D-biotin, 0.11 mg; and ethoxyquin, 125 mg.

[3] Mineral mix provided the following in milligrams per kilogram of diet: Mn, 60; Zn, 50; Fe, 30; I, 1.5; and Se, 0.5.

[4] ME – Metabolizable Energy

4.2. Trial 2

At hatch, 960 birds, Cobb 500 by product male broiler chicks, were obtained from a local hatchery and immediately placed in floor pens. Chicks were maintained on a 24 hour lighting schedule in a thermostatically controlled room. Chicks were given a standard corn-soybean meal until the 14^{th} day. After an overnight fast, chicks were weighed and assigned to treatment groups so that mean initial weights were similar among treatment groups. Body weights and feed intakes were measured 15 and 32 days of age. Chicks had *ad libitum* access to feed and water.

Each of the 4 experimental diets was replicated with 6 pens each containing 40 chicks (4 trts x 6 reps x 40 birds = 960 birds, 24 pens). All treatments were formulated to meet NRC recommendations (Table 3). Treatments 1, 2, 3 and 4 provided 3084, 2852, 2874 and 2852 kcal/kg of metabolizable energy, respectively. In treatments 3 and 4, Nutridense corn replaced conventional corn.

4. Statistical Analysis

Weekly differences between mean covariance of body weight, feed intake and feed: gain (feed conversion), among treatments were tested using Duncan's test by the general linear models procedure of SAS software. All statements of significance were based on testing at the $P < 0.05$ level.

Table 3. Composition and calculated analysis of treatment diets of the trial 2 from the performance study

Ingredients	***Treatment*** [1]			
	High Energy	Low Energy		
	1 – CC	2 - CC	3 - ND	4 - ND
	%			
Conventional Corn	56.69	55.02	-	-
Nutridense Corn	-	-	55.02	54.35
Soybean meal	36.96	37.24	37.24	37.24
Poultry fat	3.17	1.00	1.00	1.00
Sand	-	3.56	3.56	4.23
Defluorinated Phosphorus	1.70	1.70	1.70	1.70
Limestone	0.48	0.48	0.48	0.48
Vitamin mix[2]	0.25	0.25	0.25	0.25
Salt	0.35	0.35	0.35	0.35
DL-methionine	0.28	0.28	0.28	0.28
Mineral mix[3]	0.08	0.08	0.08	0.08
L-Lys-HCL	0.03	0.03	0.03	0.03
L-Thr	0.01	0.01	0.01	0.01
Calculated values				
Crude protein	21.5	21.5	21.5	21.5
ME[4], kcal/kg	3084	2852	2874	2852
Methionine	0.51	0.51	0.51	0.51
Lysine	1.20	1.20	1.20	1.20
Calcium	0.90	0.90	0.90	0.90
Available Phosphorus	0.45	0.45	0.45	0.45

[1] CC – conventional corn; ND – Nutridense corn.

[2] Vitamin mix provided the following per kilogram of diet: vitamin A, 5,510 IU; vitamin D3, 1,100 IU; vitamin E, 11 IU; vitamin B12, 0.01 mg; riboflavin, 4.4 mg; niacin, 44.1 mg; D-pantothenic acid, 11.2 mg; choline, 191.3 mg; menadione sodium bisulfate, 3.3 mg; folic acid, 5.5 mg; pyridoxine HCl, 4.7 mg; thiamin, 2.2 mg; D-biotin, 0.11 mg; and ethoxyquin, 125 mg.

[3] Mineral mix provided the following in milligrams per kilogram of diet: Mn, 60; Zn, 50; Fe, 30; I, 1.5; and Se, 0.5.

[5] ME – Metabolizable Energy

IV. Results

1. Digestibility Trial

The results presented in Table 4 indicate a higher ileal and excreta AME_n values in chicks fed ND diet than in chicks fed CC diet. The difference was 3.4 % and 3.1 % for ileal AME_n and excreta AME_n values, respectively. Ileal AME_n, was only 0.2 % lower than excreta AME_n in chicks fed a diet with CC. Also, ileal AME_n, was only 0.1 % higher than excreta AME_n in chicks fed a diet with ND.

In mature roosters fed a diet with ND, AME_n was 1.6 % greater than in mature roosters fed a diet with CC. However, for mature roosters fed a diet with ND, TME_n was only 0.2 % greater than in mature roosters fed a diet with CC.

Table 4. Metabolizable energy of conventional and Nutridense corn diet in chicks – ileum and excreta – and roosters – excreta

	Chicks[1]				Roosters[1]	
	Ileal		Excreta		Excreta	
	CC	ND	CC	ND	CC	ND
AME_n[2] (kcal/kg)	2998	3100	3003	3096	3155	3205
TME_n[3] (kcal/kg)	-	-	-	-	3482	3489

[1] CC – conventional corn; ND – Nutridense corn.

[2] AME_n – nitrogen-corrected apparent metabolizable energy.

[3] TME_n – nitrogen-corrected true metabolizable energy.

Regarding the results presented in Table 5, chicks fed a diet with ND registered a total ileal digestible amino acids value 8.5 % higher than chicks fed a diet with CC. However, lysine, on chicks fed a diet with ND, was lower by 10 % than chicks fed a diet with CC; threonine, on chicks fed a diet with ND, was higher by 6.3 % than chicks fed a diet with CC; methionine, on chicks fed a diet with ND, was lower by 28.6 % than chicks fed a diet with CC.

In mature roosters fed a diet with ND, true digestible amino acids value was 4.9 % greater than in mature roosters fed a diet with CC. Nevertheless, lysine was higher for matures roosters fed a diet with ND by 12.5 % than on mature roosters fed a diet with CC, and threonine and methionine registered values, on mature roosters fed a diet with ND, lower by 4.8 % and 17.6%, respectively, than on mature roosters fed a diet containing CC

Table 5. Total digestible amino acids (%) on ileal amino acid digestibility in chicks and true amino acid digestibility on roosters, fed conventional and Nutridense corn diets

Amino Acids	***Apparent Ileal Digestible Amino Acid in Chicks***		***True Ileal Digestible Amino Acids in Roosters***	
	CC[1]	ND[2]	CC[1]	ND[2]
	----------------------------------	%	----------------------------------	
Aspartic Acid	0,33	0,37	0,43	0,45
Threonine	0,15	0,16	0,21	0,20
Serine	0,27	0,29	0,32	0,32
Glutamic Acid	1,25	1,41	1,38	1,47
Proline	0,53	0,55	0,62	0,62
Glycine	0,22	0,21	-	-
Alanine	0,48	0,54	0,56	0,59
Cysteine	0,12	0,13	0,14	0,14
Valine	0,25	0,27	0,32	0,34
Methionine	0,14	0,10	0,17	0,14
Isoleucine	0,20	0,23	0,25	0,27
Leucine	0,80	0,95	0,94	1,02
Tyrosine	0,25	0,28	0,23	0,24
Phenylalanine	0,30	0,35	0,36	0,39
Lysine	0,20	0,18	0,21	0,24
Histidine	0,16	0,17	0,21	0,25
Arginine	0,31	0,29	0,37	0,40
Tryptophan	-	-	0,05	0,05
Total (%)	5,99	6,50	6,80	7,13

[1] CC – Conventional corn.

[2] ND – Nutridense corn.

2. *Performance Trials*

2.1. Trial 1

The objective of this study was to compare the performance of the birds fed a diet containing ND with birds fed a diet containing CC, in two levels of energy, separately. The two treatments' energy levels were not statistically compared.

From 0 to 6 days of age, there were no differences in the performance of the birds fed high energy diets (Table 6).

For birds fed on low energy treatments, there were no differences in weight gain and feed intake. However, for feed: gain ratio, chicks fed the control diet (treatment 4) registered a significantly better ($P < 0.05$) feed conversion than chicks fed ND isocaloric diet (treatment 6).

Numerically, birds on low energy treatments, fed CC control diet (treatment 4) and ND isoamount (treatment 5) diets, achieved better feed conversions than those on high energy treatments, fed CC control (treatment 1) and ND isoamount (treatment 2) diets.

Table 6. Performance of the birds fed conventional and Nutridense corn, in two levels of energy diet, from 0 to 6 days of age, on trial 1

	Treatment[1]					
	High Energy			Low Energy		
	1 - CC Control	2 - ND Isoamount	3 - ND Isocaloric	4 - CC Control	5 - ND Isoamount	6 - ND Isocaloric
Weight Gain (g/chick)	103.7	94.7	98.3	113.7	99.1	103.0
Feed Intake (g/chick)	104.0	95.4	97.6	106.1	96.6	102.3
Feed: Gain (g/g)	1.00	1.01	0.99	0.94[b]	0.97[ab]	1.00[a]

[1] CC Control – conventional corn; ND Isoamount – same % of corn as the control treatment replaced by Nutridense corn; ND Isocaloric – same caloric level as the control treatment.

[a, b] Lines with different letter superscripts differ significantly ($P < 0.05$) among high or low energy treatments.

From 7 to 13 days of age, there were no differences in the performance of the birds fed low energy diets (Table 7).

For birds fed on high energy treatments, there were no differences in weight gain and feed intake. However, for feed: gain ratio, chicks fed ND isoamount diet (treatment 2) showed a significantly better (*P* < 0.05) feed conversion than chicks fed on CC control diet (treatment 1).

Numerically, birds on high energy treatments, fed ND isoamount (treatment 2) and ND isocaloric (treatment 3) diets, achieved better feed conversions than birds on low energy treatments, fed ND isoamount (treatments 5) and ND isocaloric (treatment 6) diets.

Table 7. Performance of the birds fed conventional and Nutridense corn, in two levels of energy diet, from 7 to 13 days of age, on trial 1

	Treatment[1]					
	High Energy			Low Energy		
	1 - CC Control	2 - ND Isoamount	3 - ND Isocaloric	4 - CC Control	5 - ND Isoamount	6 - ND Isocaloric
Weight Gain (g/chick)	273.0	277.8	281.0	265.6	268.3	268.8
Feed Intake (g/chick)	332.9	321.7	328.5	320.8	330.7	336.8
Feed: Gain (g/g)	1.22[a]	1.16[b]	1.17[ab]	1.21	1.24	1.25

[1] CC Control – conventional corn; ND Isoamount – same % of corn as the control treatment replaced by Nutridense corn; ND Isocaloric – same caloric level as the control treatment.

[a, b] Lines with different letter superscripts differ significantly (*P* < 0.05) among high or low energy treatments.

From 14 to 20 days of age, there were no differences in the performance of the birds on either the high or the low energy treatments (Table 8). However, numerically, birds fed the diets on high energy treatments, registered better feed conversions than the birds fed the diets on low energy treatments. Also numerically, birds fed diets containing ND showed better feed conversion values than birds fed diets with CC, on both levels of energy treatments.

Table 8. Performance of the birds fed conventional and Nutridense corn, in two levels of energy diet, from 14 to 20 days of age, on trial 1

	Treatment[1]					
	High Energy			Low Energy		
	1 - CC Control	2 - ND Isoamount	3 - ND Isocaloric	4 - CC Control	5 - ND Isoamount	6 - ND Isocaloric
Weight Gain (g/chick)	421.0	420.2	429.4	387.7	406.8	408.6
Feed Intake (g/chick)	630.1	607.0	627.4	627.5	621.7	623.8
Feed: Gain (g/g)	1.50	1.44	1.46	1.62	1.53	1.53

[1] CC Control – conventional corn; ND Isoamount – same % of corn as the control treatment replaced by Nutridense corn; ND Isocaloric – same caloric level as the control treatment.

Overall, from 0 to 20 days of age, there were no differences in the performance of the birds on either the high or the low energy treatments (Table 9). Nevertheless, numerically, birds fed the diets on high energy treatments registered better feed conversions than birds fed the diets on low energy treatments, as well as birds fed diets containing ND, had better feed conversions than birds fed diets with CC, on both levels of energy treatments.

Table 9. Performance of the birds fed conventional and Nutridense corn, in two levels of energy diet, from 0 to 20 days of age, on trial 1

	Treatment[1]					
	High Energy			Low Energy		
	1 - CC Control	2 - ND Isoamount	3 - ND Isocaloric	4 - CC Control	5 - ND Isoamount	6 - ND Isocaloric
Weight Gain (g/chick)	797.6	780.6	808.7	759.6	774.2	776.1
Feed Intake (g/chick)	1066.9	1023.2	1053.5	1048.1	1049.0	1051.8
Feed: Gain (g/g)	1.34	1.31	1.30	1.38	1.35	1.35

[1] CC Control – conventional corn; ND Isoamount – same % of corn as the control treatment replaced by Nutridense corn; ND Isocaloric – same caloric level as the control treatment.

2.2. Trial 2

On trial 2, from 15 to 33 days of age, there were no significantly differences in weight gain on birds fed both high and low energy diets (Table 10).

For feed intake, birds fed CC high energy diet (treatment 1), showed significantly lower feed (P < 0.05) intakes than birds fed ND isoamount (treatment 3) and ND isocaloric (treatment 4) diets, on low energy treatments.

For feed: gain ratios, birds fed CC high energy diet (treatment 1), showed significantly lower (P < 0.05) feed conversions than birds fed CC control (treatment 2), ND isoamount (treatment 3) and ND isocaloric (treatment 4) diets, on low energy treatments.

Birds fed CC control (treatment 2), ND isoamount (treatment 3) and ND isocaloric (treatment 4) diets, on low energy treatments, showed no significantly differences in performance.

Table 10. Performance of the birds fed conventional and Nutridense corn, in two levels of energy diet, from 15 to 33 days of age, on trial 2

	Treatment[1]			
	High Energy	Low Energy		
	1 - CC	2 - CC Control	3 - ND Isoamount	4 - ND Isocaloric
Weight Gain (g/chick)	1476.2	1436.6	1452.9	1470.8
Feed Intake (g/chick)	2263.1^{b}	2320.8^{ab}	2350.9^{a}	2386.3^{a}
Feed: Gain (g/g)	1.53^{b}	1.62^{a}	1.62^{a}	1.62^{a}

[1] CC Control – conventional corn; ND Isoamount – same % of corn as the control treatment replaced by Nutridense corn; ND Isocaloric – same caloric level as the control treatment.

[a, b] Lines with different letter superscripts differ significantly (P < 0.05) among high or low energy treatments.

V. Discussion

1. Digestibility Trial

On the digestibility trial in chicks, CC registered similar values between ileal and excreta AME_n. The same happened in chicks fed diets with ND. It is of common knowledge that some energy is absorbed in the bird's ceca. Therefore, an excreta AME_n value should be higher than its correspondent ileal AME_n value, for the same sample of diet. Also, HOCs, like ND, are known to provide more available energy than CC (Watson and Freeman, 1975; Han *et al*., 1987; Dale and Whittle, 1991; Adams *et al*., 1994; Bartov and Bar-zur, 1995; Saleh *et al*., 1997; Parsons *et al.*, 1998; Benitez *et al*., 1999), which can be confirmed by the differences shown in this assay, in Table 4, between CC and ND. In addition, the fact that the diets formulated for each treatment had an inclusion rate of 92.25 % of each corn, would lead to more energy absorbed in the bird's ceca, reinforcing the idea of a higher difference between ileal and excreta AME_n for CC but especially for ND. However, these three factors apparently did not show on the results of AME_n in chicks, suggesting a possible human error in one step of the energy measurement method.

Dale and Whittle (1991) found that metabolizable energy content of HOC increased 37 kcal/kg for each 1 % increase in oil content. Since the difference registered in the ileal AME_n values for chicks, between CC and ND was 102 kcal/kg, and the difference registered in the excreta AME_n values for chicks, between CC and ND was 93 kcal/kg, in the present study, the results show that ND registered more 2.8 and 2.5 % of oil content, than CC, on ileal and excreta AME_n, respectively. However, in mature roosters fed ND, the amount of oil content calculated for ND was lower than the amount of oil content calculated in chicks fed ND. Having in consideration that the diet with CC and the diet with ND fed to the chicks and fed to the roosters, was exactly the same, the results obtained could have been affected by other factors not measured in this study.

For the AME_n and the TME_n, in mature rosters, it was registered more 1.4 and 0.2 % of oil content in ND than in CC. These results were lower than the ones described by Parsons *et al.* (1998), who reported that the oil content of the four corn varieties tested varied from 3.8 to 8.6 %. Nonetheless, as expected, the TME_n of the corns increased as oil content increased. The latter is in agreement with several previous reports (Han *et al*., 1987; Dale and Whittle, 1991; Bartov and Bar-Zur, 1995; Parsons *et al.*, 1998).

Although the results for energy digestibility are not in agreement between chicks and roosters in this assay, analysis of the data indicates that ND has higher metabolizable energy than CC. These results agree with previous reports, indicating higher metabolizable energy for HOC than YDC in broiler chickens (Watson and Freeman, 1975; Han *et al*., 1987; Dale and Whittle, 1991; Adams *et al*., 1994; Bartov and Bar-zur, 1995; Saleh *et al*., 1997; Parsons *et al*., 1998; Benitez *et al*., 1999), and in swine studies (Weber, 1978; Adeola and Bajjalieh, 1997). Also, Hastad *et al*., (2005) reported that metabolizable energy was approximately 4.5 % greater for ND than for YDC, in pigs.

For both the ileal and true amino acid digestibility, the total digestible amino acid values registered were greater for birds fed diets with ND than for birds fed diets with CC, which is in agreement with other reports in broiler chickens (Watson and Freeman, 1975; Han *et al*., 1987; Adams *et al*., 1994; Parsons *et al*., 1998; Benitez *et al*., 1999) and in swine trials (Adeola and Bajjalieh, 1997; Hastad *et al*., 2005). Nevertheless, based on the results of Parsons *et al.* (1998), birds fed a diet containing HOC registered more 11.7 % of total digestible amino acids than birds fed diets containing CC. Since in this study that difference was 4.9 %, a difference between the qualities of the corns in both studies is in consideration. Although it has been shown that crude protein often increases as oil increases (Watson and Freeman, 1975; Han *et al*., 1987), Dudley and Lambert (1992) reported no such relationship.

2. Performance Trials

The results obtained on birds from 0 to 6 days of age, were difficult to interpret. In a numerical observation, the better performance of birds fed the diets on low energy treatments could be due to such factors as feed intake capacity, the energy level of the diet, the inclusion rate of the corn and the absorption of the yolk sac. In such short period of time, smaller birds have limited feed intake. In this study, the mean feed intake of the chicks in this time period was 100 g. This amount for 6 days is too small to show significantly differences in performance, especially in feed conversion. Therefore, the energy level of the diet and the type of corn included in each treatment could not show clearly any influence on the results. Also, in birds of this age, there is an active absorption of the yolk sac. This absorption promotes the bird extra nutrients for growth, competing with the ones provided in the diet, leading to unclear and inconsistent results. Viera *et al*. (1997) found that chicks on starter diets (1 to 21 d of age) responded better to a CC diet supplemented with corn oil than chicks on diets with HOC. However, birds on a grower or finisher diet (21 to 42 d of age) showed no differences in performance due to the type of corn utilized. It was suggested that the immature digestive system of the chick was inefficient in digesting the intracellular oil present in HOC. Also, regarding Batal and Parsons (2002), during the early development and maturation of the digestive system in young poultry, dietary nutrients may be poorly utilized, especially during the first 7 to 10 d posthatching.

For birds from 7 to 13 days of age, there was a numerically better performance of the birds fed diets on high energy treatments with ND, than birds fed diets on low energy treatments. In this time period, the feed intake capacity of the bird increases. Therefore, the ingestion capacity decreases the effect on the results. Consequently, the energy level of the diets and the inclusion rate of each corn start to have some impact on performance. For example, the difference between treatment 2 and treatment 5, though only numerical, is mainly an effect of the energy level of the diet, and the difference between treatment 1 and treatment 2, though significantly, is mostly due to the change from CC to ND.

At this point, the effect of the yolk sac absorption is relatively small, considering its stage of evolution and the bird's weight, inducing a barely discernible impact.

It is almost clear to say that the effect of a diet is not always clear to evaluate on small birds, owing to their physical limits, as feed intake capacity, their higher susceptibility to the nearby environment and their early and fast growth and development of the small intestine.

From 14 to 20 days of age, though the results showed no significant differences between treatments, the effects of the diets' energy level and the two types of corn showed several numerical differences.

Numerically, birds on high energy treatments registered better performance than birds on low energy treatments as an effect of the diets energy level. Moreover, birds on treatments with ND showed better performance than birds on treatments with CC as an effect of the type of corn included in the diet. Both effects were clearly distinct when evaluating feed conversion.

In an overall evaluation, from 0 to 20 days of age, birds followed the tendency showed from 14 to 20 days of age, showing no significantly differences in performance of birds fed diets in both levels of the energy. It is important to point out the fact that treatments on a high energy diet had an inclusion of 3.17 % of poultry fat against none in treatments on low energy diets. These results, on this trial, go against Mateos *et al.* (1982) and Sell *et al.* (1983), who reported that supplemental dietary fat could increase intestinal retention time of feed and result in a more complete digestion of non-lipid dietary constituents, meaning more energy provided for the birds. However, ND showed no significant differences in performance over CC. Still, numerically, high energy treatments promoted birds with better feed conversions as ND achieved better results on feed conversion against CC. Although not significant, these better performances in feed conversion can represent potential saving costs, to poultry producers, on feed, in the broiler industry. As an example, two birds were evaluated for feed conversion and one registered a higher Feed: Gain ratio of 0.01, not significantly relevant in a statistical evaluation. This difference of 0.01 means that for each gram of weight gained, the bird needs to eat more 0.01 g. Therefore, if a bird eats 2000 g to reach a determined weight that would result in 20 g extra of feed spent per bird. Thus, if we assume that one poultry producer raises one million broilers per month, that would mean a 20 ton of extra feed spent in one month.

For trial 2, birds showed no significant differences in weight gain values, accounting with the two levels of energy in the treatments. Conversely, for feed conversion, treatment 1 registered significantly lower ($P < 0.05$) values than the other treatments, especially than treatment 2, where birds were fed a diet lower on energy but with the same type of corn as treatment 1. This means that even on a higher energy diet, birds fed the diet on treatment 1 recorded similar values for weight gain as birds fed the diets on low energy treatments but with a better feed conversion, showing that differences in performance were due to the energy level of the diet, and not due to the type of corn, when compared with treatment 2. This better feed conversion for treatment 1 could be, also, due to the 2.17 % higher poultry fat content on the diet compared with the low energy treatments, promoting a possible better digestibility of the nutrients in the diet. Saleh *et al.* (1997) in his study, reported that the differences in performance were related to differences in dietary energy levels and not to differences between the two types of corn. Also, it is possible that the improvements in growth rate and feed conversion reported by Han *et al.* (1987), resulted from the increased dietary energy obtained when HOC replaced YDC on a weight/weight basis (Saleh *et al*., 1997). Benitez *et al*., (1999) reported that using the latest varieties of HOC in place of CC in isonitrogenous diets with similar energy levels produced equivalent results in broilers.

In general, the results in this study are in agreement with those of several workers. Bartov and Bar-Zur (1995) found no differences in weight gain or feed intake in broilers when imported corn, Israeli HOC, or CC supplemented with corn oil to equalize fat and protein content, were compared. Mello *et al*. (1997_a) found that body weight and feed conversion were unaffected in 6-week-old broilers fed isocaloric and isonitrogenous diets containing CC, HOC, or HPC. Stillborn *et al*. (1997) also found that HOC and CC produced similar results when energy and amino acid levels were similar in both diets. In another study, Mello *et al*. (1997_b) found that CC, HOC, and HPC formulated in isocaloric, isonitrogenous diets with similar amino acid profiles did not affect 6-week body weight, weight gain, mortality, or feed conversion of broilers, although feed intake for birds fed CC was significantly ($P < 0.05$) greater than that of the others. Thus, these three varieties of corn produced comparable results in performance (Benitez *et al.*, 1999).

On the other hand, Mireles *et al*. (1996) found that complete substitution of CC (3.6% crude fat) with #80 HOC in isonitrogenous, isocaloric diets produced significantly better feed conversions with similar carcass yields. Han *et al*. (1987) showed that HOC varieties were superior to CC for poultry, due to the fact that these varieties contained higher concentrations of metabolizable energy, protein, lysine, and carotenoids than CC, thus improving growth and feed efficiency of broilers. Adams *et al*. (1994) found that substituting CC for HOC improved performance when diets were formulated to take advantage of the superior energy and amino acid content of HOC. At similar levels of dietary energy, the performance of birds was similar for all types of corn (Benitez *et al*., 1999).

Similar results were registered in swine experiments. Nursery trials conducted with HOC by Bergstrom *et al.* (1997) and De-Camp *et al.* (1998) also showed improvements in feed conversion. In growing-finishing pigs, Kendall *et al.* (1999) showed a similar improvement in feed efficiency when YDC was replaced with a HOC hybrid (Hastad *et al*., 2005).

Results from these studies indicate that using HOC can result in improved broiler performance, if feed is formulated to take advantage of the superior energy content of HOC. Also, the need to supplement rations with concentrated oils or fats could be reduced by using HOC and at the same time still meet the energy requirements of broilers but at a lower cost (Benitez *et al*., 1999).

VI. Conclusions

The results of the digestibility assay indicated a higher metabolizable energy value of ND over CC. However, for digestible amino acids, ND registered no significant differences than that of CC.

Regarding the performance trials, there were no significant differences in the performance of the birds fed CC diets and ND diets, either, from 0 to 20 days of age and from 15 to 33 days of age, relative to the type of corn administrated in the diets.

Differences in performance, relative to the energetic level of the diet, were only registered in the second trial, though there no differences in body weight among all the four treatments. However, numerically, ND allowed better performances of the birds in the first trial.

These results indicate that comparable performance of broilers can be obtained when CC is substituted with ND, turning the numerical improvements into potential saving costs in feed to poultry producers.

In the future, more research should be developed for the improvement of the nutritional traits of genetically modified ingredients in direction of a potential harmony between the producer and the animal requirements.

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